WATER RESOURCES RESEARCH GRANT PROPOSAL

Title: Reducing NPS Pollution from Onsite Sewage Disposal Systems through Improved Soil Assessment

Focus Category: WQL, WW, NU

Descriptors: Water quality, soil-water relationships, septic tanks

Duration: From March 1, 2000 To February 28, 2001

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$23,184.00	$23,184.00	$0.00
Total	Direct	Indirect

Non Federal Funds:

$47,524.00	$28,344.00	$19,180.00
Total	Direct	Indirect

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Congressional District: 03

Water Problem and Need for Research

Onsite sewage disposal systems (OSDS) have been targeted as the leading source of pollution introduced into surface water and groundwater in many regions. It has been estimated that close to 50% of the people of Alabama use OSDS as their method of domestic waste disposal for single family dwellings. When properly installed in suitable soil, these systems provide a safe and efficient disposal method for domestic waste. Unfortunately, it is apparent in certain regions of the state that a large portion of these systems are failing, and failure numbers seem to be increasing. OSDS failure manifests itself in several ways, including: 1) backing up of effluent to the soil surface (termed surfacing), and 2) leaching of untreated effluent to groundwater. With either situation, deterioration of groundwater and/or surface water quality occurs due to the off-site movement of nutrients, household chemicals, and in some cases, pathogens. In this researcher's opinion, deterioration of water quality due to OSDS failure is the largest threat to water resources in Alabama. Failures of OSDS mainly occur because the systems are installed into soils that are unsuitable due to poor drainage characteristics and/or the presence of a seasonal high water table (SHWT), which forbids additional hydraulic loading. Health department personnel and soil scientists typically use features in soil (termed *redoximorphic features*) to predict the depth to a SHWT and make proper interpretation of soil suitability to hold a functioning OSDS. However, in certain sandy soils (classified in Arenic and Grossarenic subgroups), assessment of redoximorphic features is problematic due to the nature of the sandy materials. These types of soils are termed “problem soils”. In these soils, it is difficult to predict the height of the SHWT which sometimes results in erroneous assessment for OSDS suitability. Little research exists that correlates soil redoximorphic features with water table dynamics for these soils.

These concerns have prompted interest from soil scientists with Auburn University and the Alabama Department of Public Health to develop guidelines to better assess the drainage class of certain sandy soils in the Coastal Plain of Alabama. These soils are common, approximately 25 % of Baldwin County is composed of these types of soils, and OSDS failures are occurring in this region. These soils possess thick sandy eluvial (0.5 to 1.5 m thick) horizons overlying argillic (clay-rich) horizons of reduced permeability. Past studies have shown that lateral gradients of flow associated with subsurface horizons occur in some of these soils, but uncertainties exist about the degree of *perched* water above the clay-rich horizons and the status of the SHWT. Many of these soils in lower topographical positions also possess *true* groundwater (related to regional water tables) for significant periods of the year. Because of the problematic morphology and because these soils inherently have limited abilities to sorb and renovate pollutants (e.g. from on site sewage effluent) in the sandy eluvial horizons, accelerated deterioration of water quality often occurs due to the erroneous interpretations of soil drainage class. This study is proposed to assess the drainage class and water table dynamics of these soils.

Expected Results and Benefits:

The goal of this project is to develop better guidelines for predicting the depth to SHWT in these sandy Coastal Plain soils. Results of this study will allow detailed evaluation of subtle soil features that can be used to assess hydrology and drainage class of these soils. Once features related to wetness are identified, assessment tools for professionals making decisions with regard to determining the suitability of the soil to maintain a functioning OSDS will be developed. It is projected that by accurately depicting the drainage class, better decisions can be made with regard to OSDS installation which will help limit the number of failing systems

INTRODUCTION

WATER QUALITY AND ONSITE SEWAGE DISPOSAL SYSTEMS

Deteriorating water quality is a national concern, and many workers have shown that malfunctioning onsite sewage disposal systems (OSDS) are the major pollution source in some regions (Cogger et al., 1988). Other studies have shown groundwater contamination with bacteria and nitrate increases with increasing OSDS density (Bicki and Brown, 1991). Although many sources have been identified as potential water pollutants, malfunctioning OSDS are of particular concern due to their widespread and growing use. It has been estimated that fully 40 million Americans utilize OSDS as a method of waste disposal, utilizing over 22 million systems (Nizeyimana et al., 1996). Fully 47% of the population of Alabama resides in rural or semi-rural places, and thus use OSDS for domestic waste disposal, as opposed to a centralized sewage system (Gray, 1995).

In most situations, OSDS provide a reliable and a safe way of disposing domestic sewage originating from single family dwellings. OSDS typically employ a septic tank where wastewater solids are collected and anaerobic digestion facilitates their breakdown, and a drainfield where the remaining effluent is discharged. Soil surrounding the drainfield acts as a filter which allows for renovation of effluent through physical and biochemical processes before the wastewater enters water sources. Soils retain pathogens which allows for their degradation and destruction, and soils adsorb many solutes contained in the effluent. In this manner, soils protect Alabama's water resources from pathogens, nutrients including nitrate and phosphate (which can lead to eutrophication and degradation of waterways), and household chemicals.

Unfortunately, failure of the systems occur, resulting in unsatisfactory treatment of effluent before introduction into water sources. Failures are common; it has been estimated in Alabama that upwards of 25% of the OSDS are failing (Gray, 1995). In some regions, evidence suggests failure rates may be much higher. OSDS failures result from several factors including: 1) installation into unsuitable soils, 2) improper installation of drainfield, 3) insufficient sizing of system, or 4) clogging of drain lines by bacterial mats (Zelazny et al., 1980). Failures of OSDS manifest in three ways: 1) backing up of raw sewage into the domestic dwelling, 2) movement of effluent from the drainfield onto the soil surface (called surfacing), and 3) introduction of effluent into groundwater without sufficient renovation. The last two result in rapid deterioration of water quality.

Installation of an OSDS into unsuitable soils is by far the leading cause of septic tank failure. Soil properties that render a site unsuitable for OSDS installation include the presence of a seasonal high water table (SHWT), the presence of impermeable layers that retard effluent percolation, and very coarse soil textures. Presence of a SHWT presents problems because saturated soil cannot accommodate additional hydraulic loading imposed by the effluent, thus effluent rises to the soil surface or backs into the house. Accelerated deterioration of water sources also occurs due to introduction of effluent into the water table or runoff from the soil surface. Impermeable layers in the soil do not allow for percolation of effluent through the soil media, which can restrict renovation. Extremely coarse textures facilitate rapid leaching of effluent without allowing sufficient time for biochemical processes to renovate. All of these situations render soils with these properties incapable of handling additional hydraulic loading.

Thus, it is apparent to most professionals that proper interpretation of soil drainage characteristics and depth to a SHWT could reduce the number of failing OSDS systems.

SOIL PROPERTIES

Soil forming processes (e.g., clay translocation) create soil horizons (e.g., argillic horizons or fragipans) which effect water movement in the vadose or unsaturated zone (Wilson, 1990; Blume et al., 1987; Bruce and Whisler, 1973). This unsaturated zone is where OSDS drainfields are installed. Differences in particle size and bulk density, cementation by Fe and Al oxides, and discontinuous pores create soil interfaces that may act as impermeable lenses. Subsurface argillic horizons possessing elevated clay can inhibit water infiltration because they possess hydraulic conductivities too low to allow infiltrating water to be readily transmitted. If sufficient restriction occurs, *perched* water tables can form and lateral water flow can be induced above and within these less permeable zones (Wilson et al., 1991). Perched water tables are saturated zones which may be ephemeral (during wet season) to long-lived. Perching of water induces lateral flow that can result in pollution of surface and groundwater where decreased transport times do not permit adsorption and/or degradation of pollutants in soils (Chapall et al., 1990). In areas where high densities of on site wastewater disposal systems exist accelerated contamination of groundwater occurs.

Soil scientists and hydrologists have investigated effects of subsurface features on water movement in the unsaturated zone (Ross et al., 1994; Wilson et al., 1993; Wilson et al., 1991). A significant lateral flow component on a hillslope is often associated with layers of reduced permeability relative to the overlying horizons (Bosch et al., 1994; Wilson et al., 1990). Positive pressure potentials (saturation) indicating perching of water has been shown to occur above argillic horizons (Bruce and Whisler, 1973). This perching has been shown in several studies; e.g. Wilson et al. (1990) found perched water tables above clay-rich argillic horizons in certain Ultisols in Tennessee.

Eluvial horizons (from 0.5 to 1.5m deep) of particularly sandy soils are primarily composed of sand-sized quartz grains that possess low surface areas and low cation exchange capacities. These soils have limited ability to retain nutrients or pollutants, and thus possess limited ability to adsorb septic tank effluent (STE). To complicate matters, because water sometimes moves through these sands and loamy sands at high and very high rates near saturated conditions, insufficient time exists for filtration and treatment of potential pollutants. Argillic horizons possess increased sorption capabilities, but if solutes are transported in perched water tables above or in the very upper portion of argillic horizons, little contact between solutes and reactive surfaces occurs. Therefore, the potential for ground and surface water pollution in these sandy soils is high.

WATER TABLES AND REDOXIMORPHIC FEATURES

Perched water tables are only one type found in soils. *True* groundwater tables are described as being more continuous (across the landscape) and better connected to regional groundwater flow. In reality, the distinction between these water table types in soils located in lower topographical positions is often subtle. In most situations the separation of these types are not necessary, but rather the depth to saturation or the seasonal high water table (SHWT) is the most important assessment.

The depth to the SHWT in soils caused by either perching or the presence of true groundwater is often identified by the presence of *redoximorphic features*. Redoximorphic feature development revolves around the dynamics of carbon (C), iron (Fe) and manganese (Mn) in wet soil systems, with emphasis on Fe and Mn in subsoil environments. The process that develops these redoximorphic features is as follows. When soils become saturated, aerobic microbes utilize and deplete the remaining O_2 in the system. Aerobic microbes then die or become dormant and obligate and facultative anaerobic bacteria become dominant. During anaerobic respiration soil organic matter is oxidized, and oxidized soil components act as electron acceptors and become reduced. In subsoil environments, decaying roots and dissolved organic C typically provide the labile organic matter necessary for biochemical reduction. Electron acceptors in soil systems generally follow this scheme with increasing reduction:

oxidized	O_2 to O^{-2}
	NO_3^- to N_2O or N_2
	Mn^{+4} to Mn^{+2} (at very low pH, Mn is more easily reduced than nitrate)
	Fe^{+3} to Fe^{+2}
	SO_4^{-2} to S^{-2} (H_2S)
reduced	HCO_3^-, CO_2 to CH_4

Redoximorphic feature formation in soils is due mainly to the oxidation and reduction of Fe, and to a lesser extent, Mn. In oxidized soil environments, ferric iron (Fe^{+3}) mainly exists in oxide minerals (goethite and lepidocrocite-FeOOH; and hematite-Fe_2O_3) which are red to yellow in color. Oxide minerals coat soil mineral (often silicate) surfaces and impart their characteristic colors to the soil. When reduction occurs, several things happen: 1) oxidized Fe and Mn in oxide minerals becomes reduced and subsequently soluble, and minerals begin to “dissolve”, 2) soil colors change to gray mainly due to the removal of Fe oxides and the exposure of “uncoated” silicate minerals, and 3) soluble Fe and Mn ions either concentrate and re-oxidize upon soil drying (oxidation) or are leached from the system. The gray areas where Fe oxides are removed possess low chroma colors and are termed redox depletions, whereas areas where Fe concentrates (high chroma colors) are termed redox concentrations. Most oxidation reactions are microbially facilitated. In summary, factors necessary for redoximorphic feature development include: 1) absence of oxygen, 2) presence of labile organic matter, and 3) anaerobic microbial activity. Faulkner and Patrick (1992) state that redoximorphic feature formation is not always related to period of saturation, but is controlled by organic matter amounts, temperature (related to microbial activity), degree and duration of saturation, Fe and Mn content, and landscape position. Redox potential is theoretically based on the quantity of e^- available in the soil solution, which is measured as pe or Eh (mV of potential). Therefore, most studies relating soil hydromorphology to the presence of water tables employ redox electrodes with monitoring wells to assess soil redox potential.

Several studies have examined relationships between SHWT's and redoximorphic features in soils (Vepraskas and Wilding, 1983; Guthrie and Hajek, 1979; Daniels et al., 1971). As documented by Veneman et al. (1998) in a review of soil hydromorphology studies, correlation between SHWT depths and redoximorphic features has been shown in much of the literature. These authors note two key findings in past research: 1) it is often more accurate to use the presence of redox concentrations along with redox depletions in assessing SHWT depths, and 2) several studies have shown significant saturation may occur without strong redoximorphic feature development.

Little water table research has been conducted in sandy southeastern soils, although there has been some work done in loamier soils of the region. West et al. (1998) monitored water tables for three years in predominantly Typic soils in the Coastal Plain of southwest Georgia, and found horizons with redox concentrations were saturated 20% of the time, horizons with redox depletions were saturated 40% of the time, and horizons with reduced matrices (whole horizon reduced) were saturated 50% of the time. Genthner et al. (1998) monitored a transect (mostly fine-loamy, Typic soils) in the Upper Coastal Plain of Virginia and found strong correlation between SHWT depth and the depth to redox concentrations and depletions. They also found the depth to redox depletions or a reduced matrix underestimated the height of the SHWT in well-drained soils, where as in more poorly drained soils, the opposite was true. Guthrie and Hajek (1979) recognized perching above an argillic horizon in the Coastal Plain of Alabama. Approximately 75% of the time during the 4 yr monitoring period a piezometer identified a perched water table. This horizon possessed 10YR 6/4 (munsell color notation) redox depletions in a 10YR 5/8 matrix.

SANDY SOILS-PROBLEMS

Veneman et al. (1998) outlined several factors that might result in increased difficulty to assess redoximorphic features in soils. It is generally agreed by soil scientists that extremely sandy soils present the most problems for predicting depths to a seasonal high water table. Hence, they are termed "problem soils". In sandy soils, redoximorphic feature development may be hindered by: 1) lack of C source, 2) low Fe in parent material, and 3) aerated or oxygenated water inhibiting reduction. In addition, sandy eluvial horizons typically posses low chroma matrix colors due to their low Fe content. This renders identification of low chroma redox depletions difficult. Soil scientists have for years noticed "stripping" of sand grains and other congruent features in these sandy soils without being able to affirmatively tie these to water table dynamics. This study is needed to provide a more thorough evaluation.

NATURE OF RESEARCH

Many acres of extremely sandy soils (classified in Grossarenic and Arenic subgroups of Udults) occur in the Coastal Plain of Alabama. Some of these areas are concentrated in the most rapid growing regions in the state (e.g. Baldwin county). Most of these soils exhibit an appreciable clay increase between eluvial and illuvial horizons, and many families of Arenic and Grossarenic Udults possessing variable depths to redoximorphic features are found (Table 1 & 2). Drainage class for these soils have historically been interpreted to range from somewhat poorly to somewhat excessively drained, but again, some of these assessment were made without strong indicators. Soils which are well-drained are the most suitable media for septic tank adsorption fields.

Few studies have addressed hydraulic properties and hydromorpholgy of these soils, and no studies exist which have evaluated water tables and the drainage class of soils in Arenic and Grossarenic subgroups in the Alabama Coastal Plain. Considering the importance of water table dynamics in the transport of pollutants from OSDS and the large acreage of these soils in the region, studies evaluating the depth duration and morphological indicators of seasonal high water tables are critical for understanding landscape scale water and solute movement.

Objectives

The objective of this study is to: 1) correlate the depth and duration of seasonal water tables in extremely sandy soils of the Coastal Plain of Alabama with certain redoximorphic features, and 2) establish relationships that can be used by soil scientists and health department personnel for estimating depths to SHWT for making better assessments of SDS suitability. A publication will be produced to be used as a guideline for professionals working in this arena.

Methods

Landscapes of extremely sandy soils classified in Grossarenic and Arenic subgroups will be chosen for this study. Landscapes will be located in the southeastern Coastal Plain province of Alabama, with site selection based on areas which meet soil criteria. Sites will most likely be located in Barbour or Crenshaw counties because active NRCS soil mapping in these counties would facilitate selection of sites. From these landscapes, three representative hillslopes will be selected for this study. On each hillslope, 2 to 3 sites (located most likely at the summit, backslope, toeslope of the hillslope) will be instrumented with measuring devices. At each site, soils will be described and sampled by horizon using standard Soil Survey techniques. Particular emphasis will be placed on description of morphological features thought to be related to periodic saturation and reduction.

Evaluation of saturated hydraulic conductivity (K_{sat}) of major horizons in each soil will be conducted with a Compact Constant Head Permeameter (Amoozegar, 1989). Basic characterization of each soil will include particle-size distribution (PSD), organic C, extractable cations and Al, cation exchange capacity (pH 7), and pyrophosphate, ammonium oxalate (in the dark), and dithionite-citrate-bicarbonate extractable Fe and Al.

Piezometers (non-perforated wells) will be installed at each hillslope site in nests of three. The bases of the piezometers will be placed immediately above the E/Bt horizon boundary (sandy horizon contact with more clayey horizon) to identify any perching, in the central part of the argillic/kandic horizon, and in the lower argillic/kandic horizon or underlying CB or C horizon (2 to 3 m). This will allow a comprehensive evaluation of soil-water table relationships. Piezometers will be constructed with PVC and will be read manually. Rain gauges will be placed on each site. Redox platinum electrodes will be installed (in triplicate) and connected to data loggers to assess the redox potential of the soil system. The data loggers will be centrally located to accommodate the two to three hillslope sites. Multiplexers will be used with the data loggers to increase channel capacity.

Once the depth to a SHWT is established, a thorough evaluation of the soil morphology and redoximorphic features will be undertaken which will concentrate in zones and horizons where the SHWT resides. Morphological indicators due to redox dynamics will be identified, and will be used in guideline development. Because two sites will be instrumented, it is believed a thorough evaluation can be had.

Seasonal and annual precipitation is the main extrinsic factor which controls depth to a SHWT. Thus, most researchers agree one year of SHWT evaluation is typically not sufficient. Thus, these sites will be monitored for at least one additional year. However, funding is only requested for the instrumentation, travel, and analyses for the *first year*. After this, it will be up to the researcher to provide funding for travel and associated costs. This in no way would impact completion report or other associated materials required after the year of funding.

Training Potential

This project will provide instrumentation to help support a graduate student and one undergraduate laborer. The graduate student will gain experience in hands-on instrumentation for environmental quality. Knowledge of these applications and instrumentation techniques is important for recent graduates in the environmental arena. The student will also be trained in the utilization of laboratory instruments used in environmental science, and will gain technical field and laboratory skills important to a developing soil scientist. Data handling and interpretation skills will also be provided. The student will be exposed to interpreting data to answer a practical problem using basic science. In such a manner, the graduate student will be trained on how to integrate all of these technical components to solve an important environmental concern. A M.S. degree should result from this work. The undergraduate laborer will be trained in the laboratory techniques involved with environmental monitoring and standard soil characterization. This will include field, laboratory, and data handling tasks.

Table 1. Selected characteristics of some Grossarenic Udults in the Southeastern Coastal Plain.

Series	Texture of argillic or kandic horizon	Drainage class	Redox depletions in argillic or kandic
Loamy, siliceous, subactive, thermic Grossarenic Paleudults			
Albany	sandy clay loam	somewhat poorly	yes
Blanton	sandy loam	somewhat excessive to moderately well	no
Wadley	sandy loam	well to somewhat excessive	no
Loamy, kaolinitic, thermic Grossarenic Kandiudults			
Troup	sandy clay loam	somewhat excessive	no
Loamy, siliceous, subactive, thermic Grossarenic Plinthic Paleudults			
Bonifay	sandy clay loam	well	no

Table 2. Selected characteristics of Arenic Udults in the Southeastern

Series	Texture of argillic or	Drainage class	Redox depletions in argillic or

	kandic horizons		kandic horizons
Loamy, kaolinitic, thermic Arenic Kanhapludults			
Uchee	sandy clay loam and clay	well	7/4 and 6/4 depletions
Chipola (Hap)	sandy loam	well	no
Loamy, siliceous, subactive, thermic Arenic Paleudults			
Bonneau	sandy clay loam	well to somewhat excessive	yes
Loamy, siliceous, semiactive, thermic Aquic Arenic Hapludults			
Garcon	sandy clay loam	somewhat poorly	yes
Loamy, kaolinitic, thermic Arenic Kandiudults			
Lucy	sandy clay loam	well	no
Wagram	sandy clay loam	well	no
Loamy, kaolinitic, thermic Arenic Plinthic Kandiudults			
Fuquay	sandy clay loam	well	no
Loamy, siliceous, subactive, thermic Arenic Plinthic Paleudults			
Stilson	sandy clay loam	moderately well	yes
Loamy, siliceous, subactive, thermic Arenic Plinthaquic Paleudults			

Leefield	sandy clay loam	well to somewhat poorly	yes
Loamy, siliceous, semiactive, thermic Aquic Arenic Paleudults			
Ocilla	sandy clay loam	somewhat poorly	yes

Facilities

Global Positioning System

Trimble 12 Ch ProXRS GPS, TDC, Real Time GPS receiver with OMNISTAR differential correction, C Band.

Laboratory

1) Siemens D5000 X-ray diffractometer with a single crystal monochrometer, detachable divergence and receiving slits, scintillation counter or solid state Li detector. Used for mineralogical analyses.

2) Thermal Analyst/ Dupont differential scanning calorimeter (DSC) for doing quantitative mineralogical analyses of clay samples.

3) Thermal Analyst/Dupont thermogravimetric analyses (TGA) for conducting quantitative mineralogical analyses of clay samples.

4) Autoextractor for extractable bases and cation exchange capacity measurements

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